BROADENING OF Ga II SPECTRAL LINES BY COLLISIONS WITH CHARGED PARTICLES FOR RESEARCH OF VARIABLE STARS

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Plan

1. Why Stark broadening data are important
2. How we calculate
3. Stark broadening of Ga II
4. Where we can find data for Stark broadening

NEEDS FOR LARGE STARK BROADENING DATA SET

- DEVELOPMENT OF COMPUTERS

  FOR EXAMPLE:

  PHOENIX CODE FOR MODELLING OF STELLAR ATMOSPHERES INCLUDES A PERMANENTLY GROWING DATABASA WITH ATOMIC DATA FOR MORE THAN 500 MILLIONS TRANSITIONS

- SATELLITE BORNE SPECTROSCOPY

STARK BROADENING DATA ARE NEEDED IN STELLAR PHYSICS FOR EXAMPLE FOR:

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- STELLAR PLASMA DIAGNOSTIC
- - ABUNDANCE DETERMINATIONS
- - STELLAR SPECTRA MODELLING, ANALYSIS AND SYNTHESIS

- CHEMICAL STRATIFICATION
- SPECTRAL CLASSIFICATION
- NUCLEAR PROCESSES IN STELLAR INTERIORS
- RADIATIVE TRANSFER
- STELLAR OPACITIES

- **Line shapes enter in the models of radiative envelopes by the determination of the Rosseland optical depth .**

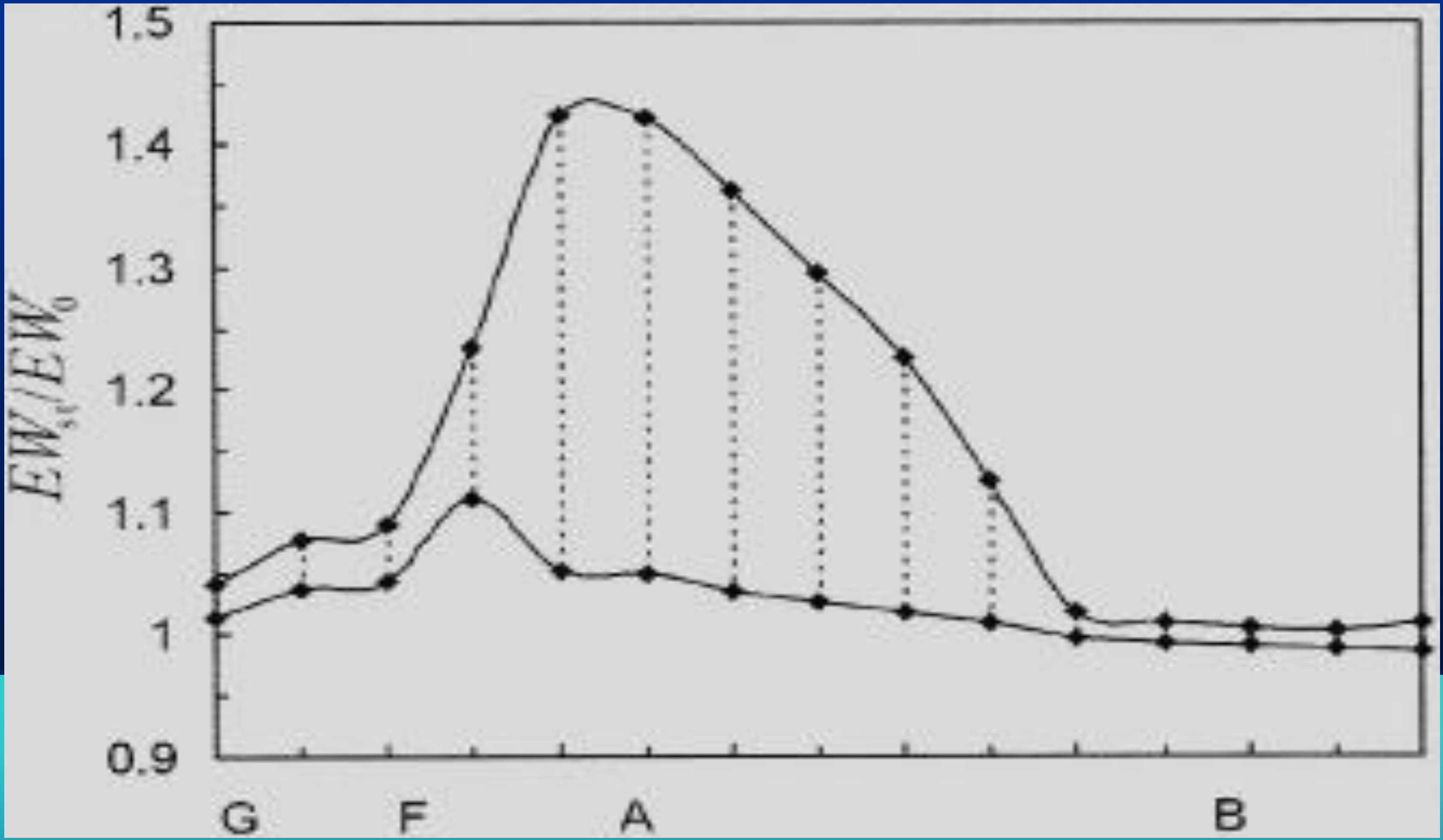
$$\tau_\nu = \int_z^\infty \kappa_\nu \rho \, dz,$$

$$\kappa_\nu = N(A, i) \phi_\nu \frac{\pi e^2}{mc} f_{ij},$$

$$\frac{dI_\nu}{ds} = -K_\nu I_\nu + \varepsilon_\nu$$

RADIATIVE TRANSFER EQUATION

Maximal (upper line) and minimal (lower line) of the ratio of equivalent widths for different stellar types. Maximal and minimal value of EWSt/EW0 are given for 38 considered Nd II lines.



- THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 135:109-114, 2001
- *STARK BROADENING EFFECT IN STELLAR ATMOSPHERES: Nd II LINES*
- L. C. POPOVIC , S. SIMIC,
- N. MILOVANOVIC, M. S.DIMITRIJEVIC

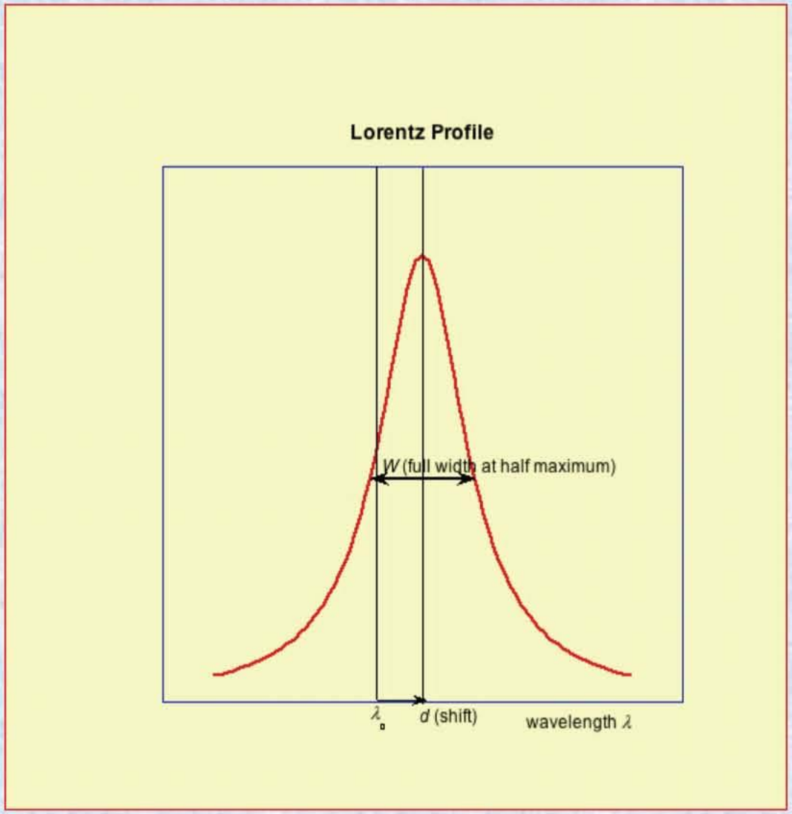
STARK BROADENING theory and calculations

based on the founding papers by Baranger (1958) in the impact approximation

- ***Impact approximation***
  - *Collisions between radiators and perturbers act independently and are additive*
- ***Complete collision approximation***
- ***Isolated lines***
  - *Neighbouring levels do not overlap*

–> LORENTZ PROFILE:

•***width*** *and* ***shift***
depend on the medium *(density, temperature)*



semiclassical results for "Stark" broadening of isolated lines of atoms and ions in the impact approximation-1

$$W = N\int v\, f(v)\left(\sum_{i'\neq i}\sigma_{ii'}(v)+\sum_{f'\neq f}\sigma_{ff'}(v)+\sigma_{el}(v)+\sigma_R\right)$$

$$\sum_{i'\neq i}\sigma_{ii'}(v)=\frac{1}{2}\pi R_1^2+\int_{R_1}^{R_D}2\pi\rho\,\mathrm{d}\rho\sum_{i'\neq i}P_{ii'}(\rho,v)$$

$$P_{ii'}(\rho,v)=\frac{1}{\hbar^2}\left|\int_{-\infty}^{+\infty}V_{ii'}\exp\left(-\frac{\mathrm{i}}{\hbar}\Delta E_{ii'}\,t\right)\right|^2$$

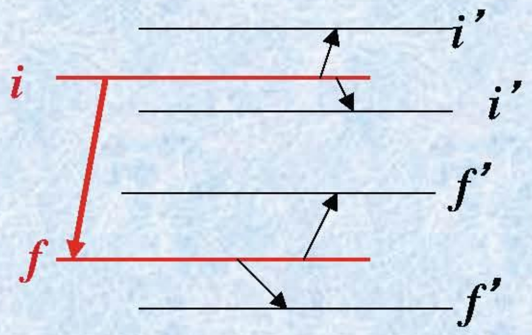
$$\sigma_{el}=2\pi R_2^2+\int_{R_2}^{R_D}2\pi\rho\,\mathrm{d}\rho\sin^2\delta$$

$$\delta=\left(\phi_p^2+\phi_q^2\right)^{1/2}$$

$$\phi_p=\sum_{i'\neq i}\phi_{ii'}-\sum_{f'\neq f}\phi_{ff'}$$

$$d=N\int v\, f(v)\int_{R_3}^{R_D}2\pi\rho\,\mathrm{d}\rho\sin 2\phi_p$$

σ_R = Feshbach resonances contribution for ions emitters.



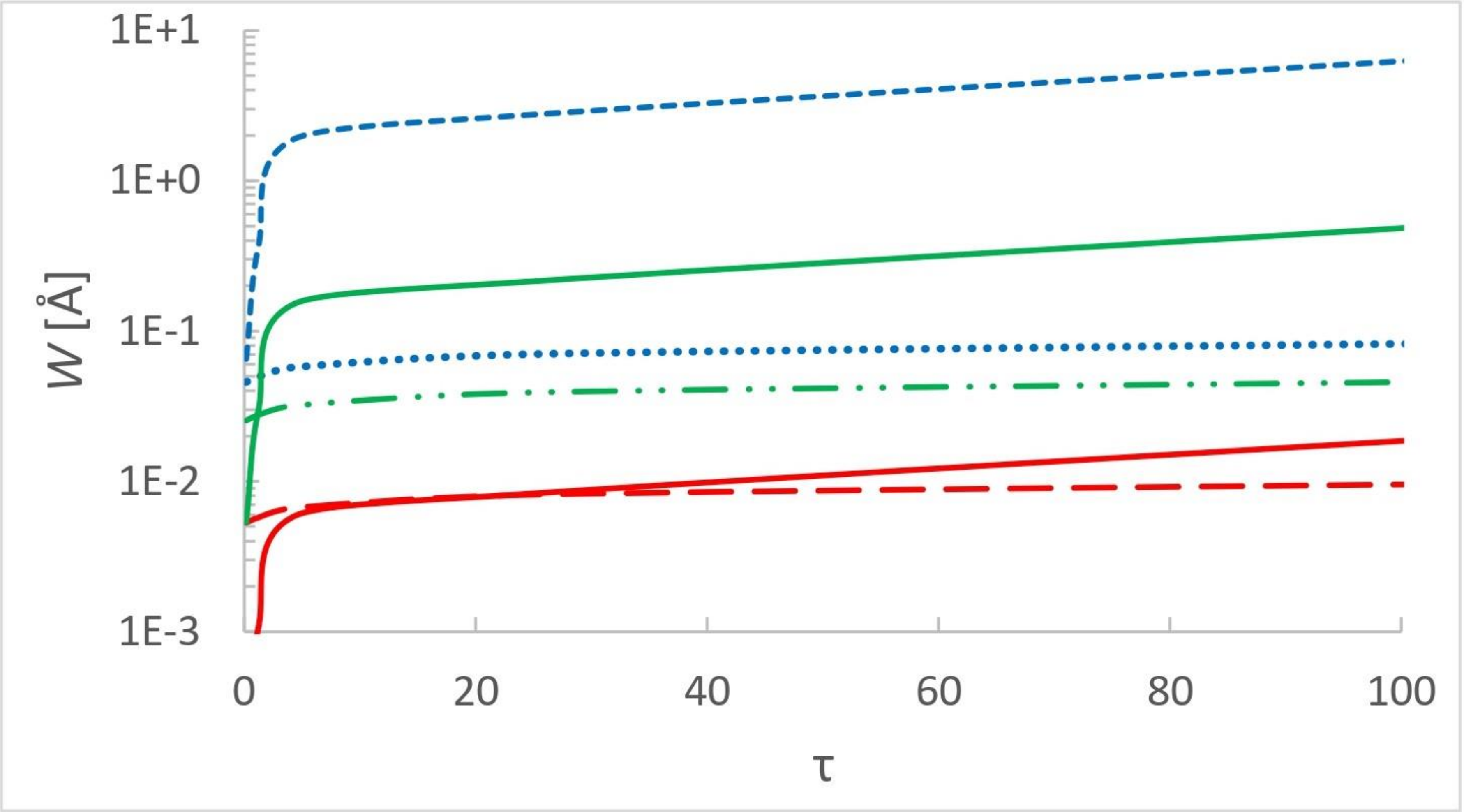
PERTURBER DENSITY = 1.E+16 cm-3

TRANSITION	T(K)	ELECTRONS WIDTH(A)	ELECTRONS SHIFT(A)	PROTONS WIDTH(A)	PROTONS SHIFT(A)	IONIZED HELIUM WIDTH(A)	IONIZED HELIUM SHIFT(A)
SINGLETS							
Ga II 4p-5d	5000.	0.185E-01	0.167E-02	0.179E-02	-0.318E-03	0.198E-02	-0.271E-03
1449.2 A	10000.	0.150E-01	0.168E-02	0.211E-02	-0.466E-03	0.226E-02	-0.393E-03
C= 0.50E+18	20000.	0.128E-01	0.133E-02	0.237E-02	-0.586E-03	0.249E-02	-0.480E-03
	30000.	0.120E-01	0.147E-02	0.251E-02	-0.651E-03	0.256E-02	-0.532E-03
	50000.	0.113E-01	0.124E-02	0.264E-02	-0.746E-03	0.262E-02	-0.608E-03
	100000.	0.105E-01	0.955E-03	0.274E-02	-0.868E-03	0.276E-02	-0.678E-03
Ga II 5p-5d	5000.	0.255	-0.171E-01	0.276E-01	-0.760E-02	0.296E-01	-0.658E-02
5221.1 A	10000.	0.214	-0.146E-01	0.321E-01	-0.109E-01	0.340E-01	-0.882E-02
C= 0.64E+19	20000.	0.195	-0.145E-01	0.363E-01	-0.133E-01	0.374E-01	-0.108E-01
	30000.	0.192	-0.116E-01	0.382E-01	-0.148E-01	0.381E-01	-0.122E-01
	50000.	0.190	-0.122E-01	0.402E-01	-0.166E-01	0.400E-01	-0.131E-01
	100000.	0.187	-0.104E-01	0.424E-01	-0.191E-01	0.411E-01	-0.152E-01
Ga II 4d-4f	5000.	0.630	0.127	0.473E-01	0.232E-01	0.533E-01	0.201E-01
8964.6 A	10000.	0.523	0.103	0.597E-01	0.332E-01	0.621E-01	0.269E-01
C= 0.19E+20	20000.	0.470	0.868E-01	0.702E-01	0.403E-01	0.710E-01	0.329E-01
	30000.	0.457	0.769E-01	0.761E-01	0.448E-01	0.755E-01	0.367E-01
	50000.	0.454	0.653E-01	0.830E-01	0.506E-01	0.780E-01	0.398E-01
	100000.	0.451	0.550E-01	0.907E-01	0.581E-01	0.796E-01	0.460E-01

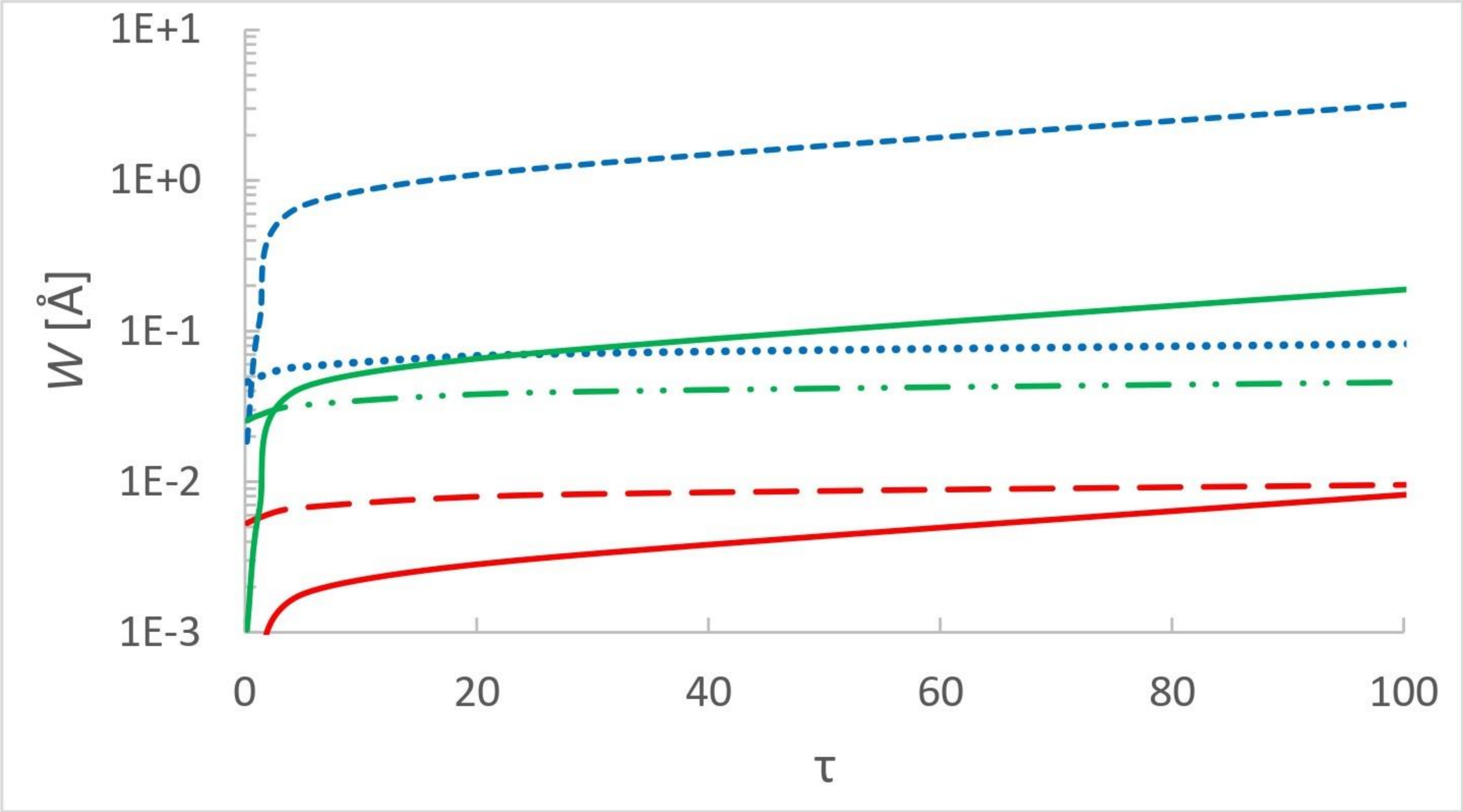
Teff=8500, log g =4.5

TRIPLETS	T	We	wp	WDoppler
Ga II 4p-5d	7602.	0.209E-03	0.448E-04	0.00531
1125.0 A	8930.	0.106E-02	0.273E-03	0.00575
C= 0.20E+15	11980.	0.588E-02	0.170E-02	0.00667
	17938.	0.833E-02	0.309E-02	0.00816
	26137.	0.224E-01	0.102E-01	0.00984
Ga II 5p-5d	7602.	0.535E-02	0.104E-02	0.0254
5391.0 A	8930.	0.296E-01	0.635E-02	0.0276
C= 0.47E+16	11980.	0.152	0.400E-01	0.0319
	17938.	0.215	0.716E-01	0.0391
	26137.	0.584	0.235	0.0472
Ga II 5d-5f	7602.	0.652E-01	0.184E-01	0.0458
9696.1 A	8930.	0.364	0.111	0.0496
C= 0.39E+16	11980.	1.90	0.645	0.0574
	17938.	2.76	1.20	0.0703
	26137.	7.54	3.98	0.0849

Teff=8500 K log g =4.5



Teff =8500 K log g = 4.5



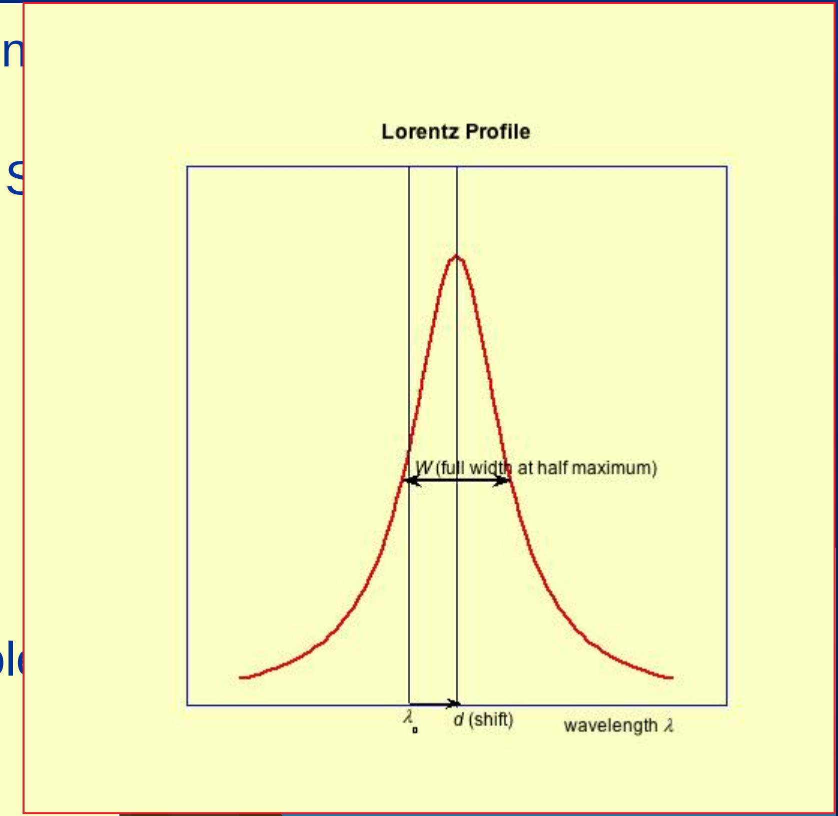
STARK-B

Database for "Stark" broadening of isolated lines of atoms and ions in the impact approximation

S. Sahal-Bréchot*, M.S. Dimitrijević**(scientists responsibles of Stark-b)
and N. Moreau*(Research engineer)
**Observatoire de Paris, LERMA, France*
*** Astronomical Observatory of Belgrade, Serbia*

Calculated widths and shifts contained in more than **100 publications** (1984-2009)

- **Theory and Numerical code** created by S. Sahal-Bréchot *(1969 first version, 1974 complex atoms, 1977 addition of Feshbach resonances for ions):* ***SCP*** *(about 6-8 basic papers)*
- **Updated** by M.S. Dimitrijević and S. Sahal-Bréchot
- **Accuracy** : about 20%, sometimes better, sometimes less
- **More than 1500 citations** (ADS) for the whole work



80% of the data are currently implemented but the database has been opened since september 2008

l'Observatoire de Paris — LERMA
Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique

STARK-B http://stark-b.obspm.fr

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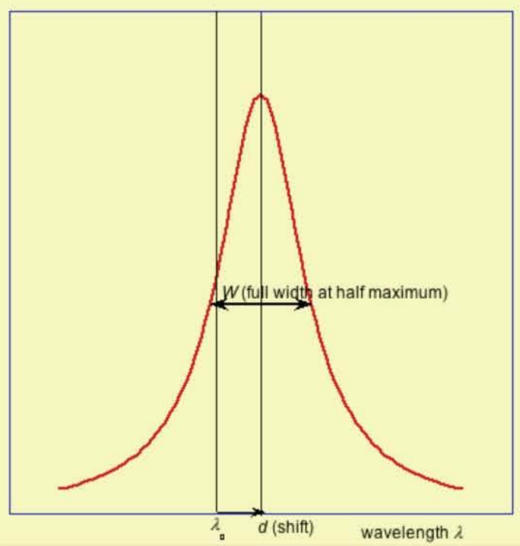
STARK-B

Database for "Stark" broadening of isolated lines of atoms and ions in the impact approximation

Lorentz Profile



The STARK-B database is now fully opened though not yet complete.

Last data update : 2012-03-30

MOLAT l'Observatoire de Paris Astronomical Observatory, Belgrade

Ionization degree of the element

Si I   Si II   Si IV   Si V   Si VI   Si XI   Si XII   Si XIII

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
				Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
				Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

VAMDC consortium   LERMA   l'Observatoire de Paris | PSL   PADC Paris Astronomical Data Centre   Astronomical Observatory, Belgrade

VAMDC

Virtual Atomic and Molecular Data Centre

THANK YOU FOR ATTENTION